

Contents

Foreword to Third Edition	V
Preface to Third Edition	VII
Foreword to Previous Editions	IX
Prefaces to Previous Editions	XI
Preface to First Edition	XI
Preface to Second Edition	XIV
1 Introduction	1
1.1 Reader Expectations	2
1.2 Harmful Beliefs	3
1.3 Snap-Fit Technology	4
1.4 Snap-Fits and Loose Fasteners	6
1.5 Snap-Fits as Interface Systems	6
1.5.1 Feature Level	7
1.5.2 Attachment Level	7
1.6 The Attachment Level Construct® (ALC)	9
1.6.1 Attachment Level Terminology	9
1.6.2 Applying the ALC to Other Attachment Methods	10
1.6.3 Required Capabilities for Snap-Fit Development	10
1.6.4 Justifying the ALC	11
1.7 Using This Book	12
1.7.1 Sample Parts	14
1.7.2 Snap-Fit Novices	15
1.7.3 Experienced Product Developers	16
1.7.4 Design for Assembly/Manufacturing Practitioners	16
1.7.5 Executives and Engineering Managers	17
1.8 Summary	17

2	Key Requirements	19
2.1	Constraint	19
2.2	Compatibility	21
2.3	Robustness	24
2.4	Strength	24
2.5	Summary	26
3	Introduction to the Snap-Fit Development Process	29
3.1	Concept vs. Detailed Design	30
3.2	The Value of Multiple Concepts	31
3.3	Step 0: Is a Snap-Fit Appropriate?	32
3.4	The Demand-Complexity Matrix®	36
3.5	Summary	38
4	Descriptive Elements	41
4.1	Function	41
4.1.1	Action	42
4.1.2	Purpose	43
4.1.3	Retention	43
4.1.4	Release	44
4.2	Basic Shapes	45
4.2.1	Mating-Part and Base-Part	45
4.2.2	Basic Shape Descriptions	46
4.2.3	Basic Shape Combinations	47
4.3	Engage Direction	50
4.4	Assembly Motion	52
4.5	Summary	54
5	Physical Elements: Locators	55
5.1	Protrusion-Based Locators	56
5.1.1	Pins	56
5.1.2	Prongs	57
5.1.3	Tabs	58
5.1.4	Lugs	58
5.1.5	Tracks	58
5.1.6	Cones	59
5.1.7	Wedges	59
5.1.8	Catches	60
5.2	Surface-Based Locators	60
5.2.1	Surfaces	60
5.2.2	Edges	61
5.2.3	Lands	61

5.3	Void-Based Locators	61
5.3.1	Holes	62
5.3.2	Slots	62
5.3.3	Cutouts	62
5.4	Living Hinges	63
5.5	Using Locators	63
5.5.1	Locator Pairs	63
5.5.2	Providing Constraint	65
5.5.3	Assembly Motion and Strength	66
5.5.4	Fine-Tuning	68
5.5.5	Dimensional Robustness	69
5.5.5.1	Positioning	69
5.5.5.2	Compliance	71
5.5.5.3	Datum Points	72
5.5.6	Constraint Efficiency	72
5.5.7	Mechanical Advantage and Stability	73
5.5.8	Ease of Assembly	74
5.6	Summary	74
6	Physical Elements: Locks	77
6.1	Lock Deflection and Separation Behavior	78
6.2	Lock Styles	80
6.3	Cantilever Beam Locks	81
6.3.1	Hooks	84
6.3.1.1	Hook Assembly Behavior	86
6.3.1.2	Hook Separation Behavior	88
6.3.1.3	Hooks and Retainers	91
6.3.1.4	Hooks and Prongs	92
6.3.2	Loops	93
6.3.2.1	Loop Assembly Behavior	94
6.3.2.2	Loop Separation Behavior	95
6.3.2.3	Loops and Knit Lines	96
6.3.3	Traps	98
6.3.3.1	Trap Assembly Behavior	101
6.3.3.2	Trap Separation Behavior	101
6.3.4	Low Deflection Lugs	103
6.3.5	Other Cantilever Beam Locks	104
6.4	Planar Locks	105
6.5	Torsional Locks	107
6.6	Annular Locks	107
6.7	Using Locks	108
6.7.1	Lock Pairs	108
6.7.2	Short Grip-Length and Low-Clearance Applications	109

6.7.3	High Demand Applications	110
6.7.4	Tamper Resistant Applications	111
6.7.5	The Case against Cantilever Hooks	111
6.8	Summary	113
7	Lock Strength and Decoupling	117
7.1	Level 0 No Decoupling	119
7.2	Level 1 Decoupling	120
7.3	Level 2 Decoupling	121
7.4	Level 3 Decoupling	124
7.5	Level 4 Decoupling	125
7.6	Summary	130
8	Constraint in Snap-Fit Applications	133
8.1	Perfect Constraint	134
8.2	Proper Constraint	136
8.3	Under-Constraint	137
8.4	Over and Improper Constraint	139
8.4.1	Redundant Constraint Features	140
8.4.2	Opposing Constraint Features	141
8.5	The Constraint Worksheet	145
8.6	Using the Constraint Worksheet	151
8.7	Constraint Rules	156
8.8	Summary	157
9	Physical Elements: Enhancements	159
9.1	Assembly Enhancements	160
9.1.1	Guides	161
9.1.2	Clearance	163
9.1.3	Pilots	164
9.1.4	Example: Switch Application	165
9.1.5	Example: Reflector Application	168
9.1.6	Feedback	172
9.2	Activation Enhancements	176
9.2.1	Visuals	176
9.2.2	Assists	179
9.2.3	User-Feel	180
9.3	Performance Enhancements	182
9.3.1	Guards	182
9.3.2	Retainers	183
9.3.3	Compliance	184
9.3.3.1	Local Yield	185

9.3.3.2	Elasticity	187
9.3.3.3	Isolators	187
9.3.4	Back-Up Features	187
9.4	Manufacturing Enhancements	189
9.4.1	Process-Friendly Design	190
9.4.2	Fine-Tuning Enablers	193
9.5	Summary	197
10	Applying the Snap-Fit Development Process	203
10.1	Step 1: Define the Application	204
10.2	Step 2: Benchmark	206
10.3	Step 3: Generate Multiple Concepts	210
10.3.1	Engage Direction	211
10.3.2	Assembly Motions	212
10.3.3	Identify Constraint Pairs	215
10.3.4	Add Some Enhancements	220
10.3.5	Select a Concept for Analysis	221
10.4	Step 4: Design and Analyze Features	222
10.4.1	Lock Alternatives	223
10.4.1.1	Threaded Fasteners	223
10.4.1.2	Plastic Push-In Fasteners	225
10.4.1.3	Spring-Steel Clips	226
10.5	Step 5: Confirm Design with Parts	227
10.6	Step 6: Fine-Tune the Design	230
10.7	Step 7: Snap-Fit Application Completed	231
10.8	Summary	231
11	Feature Development: Material Properties	233
11.1	Sources of Material Property Data	233
11.2	Material Property Assumptions	234
11.3	The Stress-Strain Curve	235
11.4	Determining a Design Point	239
11.4.1	Applications with Fixed Strain	239
11.4.2	Applications with Variable Strain	240
11.4.3	The Secant Modulus	242
11.4.4	Maximum Permissible Strain Data	242
11.5	Coefficient of Friction	244
11.6	Other Effects on Material Properties	246
11.7	Summary	249
12	Lock Feature Development: Rules-of-Thumb	251
12.1	Beam-Based Locks	251
12.1.1	Beam Thickness at the Base	253

12.1.2	Beam Length	255
12.1.3	Beam Thickness at the Retention Feature	256
12.1.4	Beam Width	257
12.2	Retaining Member: Catch	259
12.2.1	The Insertion Face	259
12.2.2	The Retention Face	260
12.3	Loops	262
12.4	Traps	263
12.5	Other Lock Styles	265
12.5.1	Torsional Locks	265
12.5.2	Planar Locks	265
12.5.3	More Lock Styles	266
12.6	Summary	268
13	Lock Feature Development: Calculations	269
13.1	Assumptions and Allowances	270
13.2	The Deflecting Member: Cantilever Beam	272
13.2.1	General Equations for Rectangular Sections	273
13.2.2	Constant Section Beam Bending	274
13.2.3	Adjusting the Design Strain for Stress Concentration	277
13.2.4	Calculating the Initial Beam Strain	279
13.2.5	Adjusting for Deflection at the Beam's Base	279
13.2.6	Calculating the Initial Beam Deflection Force	283
13.2.7	Adjusting for Mating Feature/Part Deflection	283
13.2.8	Example Beam Strain and Deflection Calculations	285
13.2.9	Deflection Graphs for a Straight Beam	292
13.3	Deflecting Member: Tapered Beams	296
13.3.1	Taper Error Example	297
13.3.2	Beams Tapered in Thickness	299
13.3.3	Beams Tapered in Width	304
13.4	Beam Calculation Summary	307
13.5	Other Deflecting Member Styles	308
13.5.1	Other Beam-Based Styles: Loops and Traps	308
13.5.2	Other Styles: Torsional, Annular, and Planar Deflection	310
13.6	The Retaining Member: Catch	311
13.6.1	Lock Assembly Force	312
13.6.1.1	Adjusting for the Insertion Face Effective Angle	312
13.6.1.2	Example Assembly Force Calculations	314
13.6.1.3	Modifying the Insertion Face Profile	315
13.6.2	Catch Separation Force	319
13.6.2.1	Adjusting for the Retention Face Effective Angle ...	319
13.6.2.2	Example Assembly Force Calculations	321
13.6.2.3	Modifying the Retention Face Profile	323

13.7	Stationary Catches and Traps as Retaining Members	325
13.7.1	Other Separation Considerations	328
13.8	Using Finite Element Analysis	329
13.9	Calculation Spreadsheets	330
13.10	Summary	333
14	Diagnosing Snap-Fit Problems	337
14.1	Common Snap-Fit Mistakes	339
14.2	Attachment Level Diagnosis	340
14.3	Feature Level Diagnosis	341
14.4	Summary	347
15	Gaining a Competitive Advantage in Snap-Fit Technology ...	349
15.1	Terminology	351
15.2	Managing Expectations	352
15.3	Harmful Beliefs	353
15.4	The Demand-Complexity Matrix	355
15.5	The Snap-Fit Capability Plan	360
15.5.1	Vision, Mission, and Values	361
15.5.2	Objectives	361
15.5.3	Strategies	361
15.6	Initiatives for Getting Started	363
15.6.1	Provide Education and Training	364
15.6.2	Provide Technical Resources	364
15.6.3	Identify Low-Impact Applications as a Starting Point	364
15.6.4	Use Physical Models	365
15.6.5	Provide Benchmarking Opportunities	365
15.6.6	Include Snap-Fit Technical Requirements in the Bidding and Purchasing Processes	366
15.6.7	Identify Intermediate Applications	368
15.7	Initiatives for Organizational Capability	369
15.7.1	Identify and Empower a Snap-Fit Champion	369
15.7.2	Identify and Empower a Snap-Fit Technical Leader	369
15.7.3	Make Snap-Fit Technology Visible in the Organization	370
15.7.4	Link Snap-Fits to Other Business Strategies	370
15.7.5	Create and Maintain a Library of Preferred Concepts	370
15.7.5.1	Example of a Preferred Concepts Initiative	372
15.7.6	Have a Model of the Snap-Fit Technical Domain	375
15.7.7	Reward Teamwork and Make Snap-Fits Interesting	375
15.7.8	Identify Supportive Customers and Suppliers	375
15.8	Summary	376

Appendix – Resources	379
About the Author	383
Index	385